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Radiotherapy techniques

IMRT in clinical practice – introduction of new QA procedures

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The goal of radiotherapy is to deliver the dose precisely to the target volume leaving the healthy tissues spared. With a new modality of three-dimensional conformal radiotherapy (3D-CRT) – intensity modulated radiation therapy (IMRT) – maintaining low level treatment toxicity within the critical organs and increasing total tumor dose becomes more likely.
IMRT combines two concepts of 3D-CRT delivery: inverse treatment planning with computer optimization and computer controlled intensity modulation of the beam during the treatment. Due to high conformality of IMRT plans it is very important to develop proper quality assurance (QA) protocols for treatment planning and to implement them in clinical practice.
In the Maria Sklodowska-Curie Memorial Cancer Center and Institute of Oncology at Gliwice, Poland an IMRT planning system CadPlan-Helios (Varian) has been in use since October 2000. Treatment is delivered by four accelerators: two Clinac 2300 and two Clinac 600, all equipped with dynamic multileaf collimator option (dMLC).
The aim of this paper is to present our experiences with the IMRT technique implementation in clinical practice with particular regard to new quality assurance procedures.

Nowe procedury kontroli jakości w radioterapii z modulacją intensywności wiązki

Celem planowania leczenia w radioterapii jest dostarczenie możliwie wysokiej dawki promieniowania w obszar guza z jednoczesną maksymalną ochroną tkanek zdrowych. Nowa technika w radioterapii – modulacja intensywności wiązki (IMRT) – pozwala na utrzymanie niskiego ryzyka powikłań ze strony narządów krytycznych przy eskalacji dawki w obszarze guza.
IMRT łączy w sobie dwie koncepcje konformalnej radioterapii: odwrotne planowanie leczenia i komputerową optymalizację oraz komputerowo sterowaną modulację intensywności wiązki podczas napromieniania. Ze względu na bardzo dużą precyzję, jaką narzuca na użytkownika IMRT, konieczne jest opracowanie i wdrożenie w praktyce klinicznej szczegółowych procedur kontroli jakości radioterapii (QA).
W Centrum Onkologii – Instytucie w Gliwicach IMRT została po raz pierwszy zastosowana w październiku 2000 roku. Planowanie IMRT jest przeprowadzane za pomocą systemu CadPlan-Helios, natomiast leczenie za pomocą dwóch akceleratorów Clinac 2300 i dwóch Clinac 600; wszystkie wyposażone w opcję dynamicznego kolimatora wielolistkowego (dMLC).
Celem pracy jest przedstawienie kolejnych etapów planowania i leczenia w oparciu o modulację intensywności wiązki ze szczególnym uwzględnieniem nowych procedur kontroli jakości w IMRT, związanych z weryfikacją prowadzonego napromieniania.

Key words: intensity modulated radiation therapy, conformal radiotherapy, quality assurance
Słowa kluczowe: modulacja intensywności wiązki, radioterapia konformalna, kontrola jakości radioterapii

Introduction

The goal of radiotherapy is to deliver the dose precisely to the target volume leaving the healthy tissues spared. With a new modality of three-dimensional conformal radiotherapy (3D-CRT) – intensity modulated radiation therapy (IMRT) – maintaining low level treatment toxicity within the cristical organs and increasing total tumor dose becomes more likely. [1, 2]. The idea behind IMRT is to create a set of static fields with multileaf collimator leaves (MLC) moving while the beam is on. Thus the shape of the irradiated field changes during irradiation. In conventional radiotherapy "flat" intensity fields are applied. In IMRT such fields are replaced by "non uniform" intensity modulated beams.

IMRT combines two concepts of 3D CTR delivery: inverse treatment planning with computer optimization and computer controlled intensity modulation of the beam during the treatment. Due to high conformali-

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ty of IMRT plans it is very important to develop proper quality assurance (QA) protocols for treatment planning process and their implementation in clinical practice [3, 4].

The aim of this paper is to present the steps of IMRT planning and application in clinical practice with particular regard to new QA procedures for treatment verification (electronic portal imaging, independent treatment time calculations) [1, 5, 6].

IMRT in the Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Gliwice, Poland

The Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology at Gliwice, Poland has been using the IMRT planning system CadPlan-Helios (Varian) since October 2000. Over 60 patients have already been treated (head and neck cancers, prostate, lung, brain, rectum, retroperitoneal space tumors). The Radiotherapy Department in Gliwice is equipped with two Clinac 2300 accelerators, two Clinac 600 accelerators (Varian) and two cobalt units. Dynamic MLC option is installed in all Clinac accelerators. Cadplan-Helios program computers and accelerators are connected via VARiS Management System. IMRT computer treatment planning process includes visualization with contour definition, beam geometry set-up, dose calculations, treatment and verification. The detailed steps of IMRT planning procedures are shown in Figure 1.

The new concept of IMRT is inverse planning (computer optimization function), thus differing from conventional radiotherapy

Contour definition

Exact contouring is critical for precise treatment planning. In the IMRT technique particular impact is put on the Planning Target Volume (PTV) definition due to very high conformity of the treatment. Cristical structures must also be contoured in order to control and minimize the risk of treatment complications.

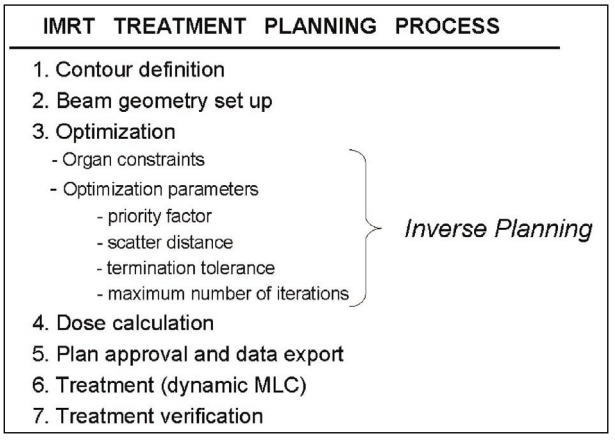

Figure 1. IMRT treatment planning process

Beam geometry set-up

The treatment planner selects various field sizes and the beam angle and its weight to irradiate the specific tumor volume. The dose contributions to the target, and to other organs, are evaluated by the planner and used to choose optimal combination of the beams. In IMRT planning the beam set-up is based on our experience gathered on non-conformal and conformal planning. The CadPlan-Helios requires a number of fields, beam directions and beam energy to be selected by the planner. Due to non-uniform IMRT beams one should avoid opposing fields and creating non-coplanar beam set-up.

Optimization process

Before starting the optimization program, organ constraints and optimization parameters must be specified. Basing on pre-defined parameters the CadPlan-Helios generates leaf motion patterns, produces the actual fluence map and animates dMLC delivery. The set of dose constraints covers minimum and maximum doses for particular volumes and dose-volume restrictions. The definition of dose constraints bases on clinical experience, but radiobiological data should also be considered. Organ constraints are determined individually for each patient. In the CadPlan-Helios there is a possibility to memorise constraints and reload them for other patients, however the definition of constraints for the volume of interest constitutes a very individual part of the treatment.

Optimization parameters are:

- priority factor (specifies the clinical significance of dose limits for a particular structure)
- scatter distance (determines the matrix scatter taken into account in computer calculations)
- termination tolerance (automatic stop value for optimization function)
- maximum number of iterations

Dose calculations

Computer dose calculations are performed by the Cadplan-Helios treatment planning system v. 6. 1. 5 (Varian).

Plan approval and data export

The final treatment plan presented by the computer is approved by a physicist. Next treatment data are enetered into the VARiS Management System connected via network to the accelerators.

Treatment (dynamic MLC option)

Treatment is performed on a Clinac accelerator equipped with dMLC option version 5.4.

Treatment verification

Treatment verification (Figure 2) is performed on two levels: graphic and dosimetric. Some verification procedures (e.g. treatment time and isocenter location) are conducted before the treatment, some already on the accelerator. The number of monitor units (MU) is calculated by the treatment planning system. While the verification of

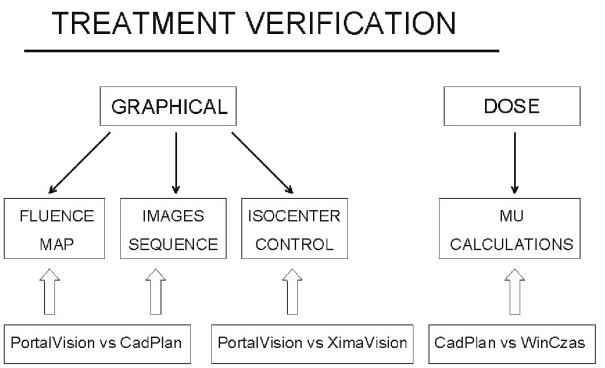

Figure 2. IMRT – verification of the treatment

these values is performed by an independent MU calculation program named Winczas® (Figure 4) originally designed in our Institute and successfully utilized in routine clinical practice. The main objective of independent calculation is to find the major errors in field size or beam energy. The Cadplan-Helios calculations still remain the basis for treatment. All IMRT patient data are stored in a database, which allows to analyze differences in MU between CadPlan-Helios and Winczas® for particular patients and/or for all patients.

The isocenter control is conducted every day prior to the actual treatment. In order to verify the isocenter position (the control of patient positioning) two geometrically identical orthogonal (0° and 90°) images are taken during the real treatment and compared with corresponding images taken during simulation [6].

Localization port films are obtained for each intensity modulated field with the MLC set to the "start" position of the leaves and consecutive leaves positions till the "stop" position. The image sequence verification allows to compare consecutive segments of MLC leaves position calculated by CadPlan-Helios with corresponding segment images obtained by electronic portal imaging (Figure 3). This procedure verifies that the radiation is properly directed (relative to the bony structures) and modulated by MLC leaves. Although such verification is time-consuming it is also of crucial value [5, 7-9].

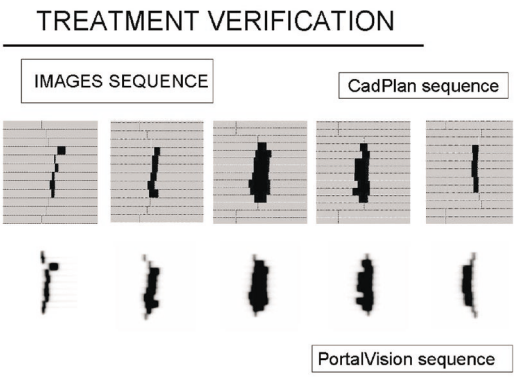

Figure 3. Comparison of segments calculated by the CadPlan-Helios and obtained from electronic portal imaging

IMRT is a time-consuming process; it begins with contour definition and ends with treatment verification. Thus all indications for IMRT must be carefully considered [10, 11]. On the other hand it allows for a "sculptu-

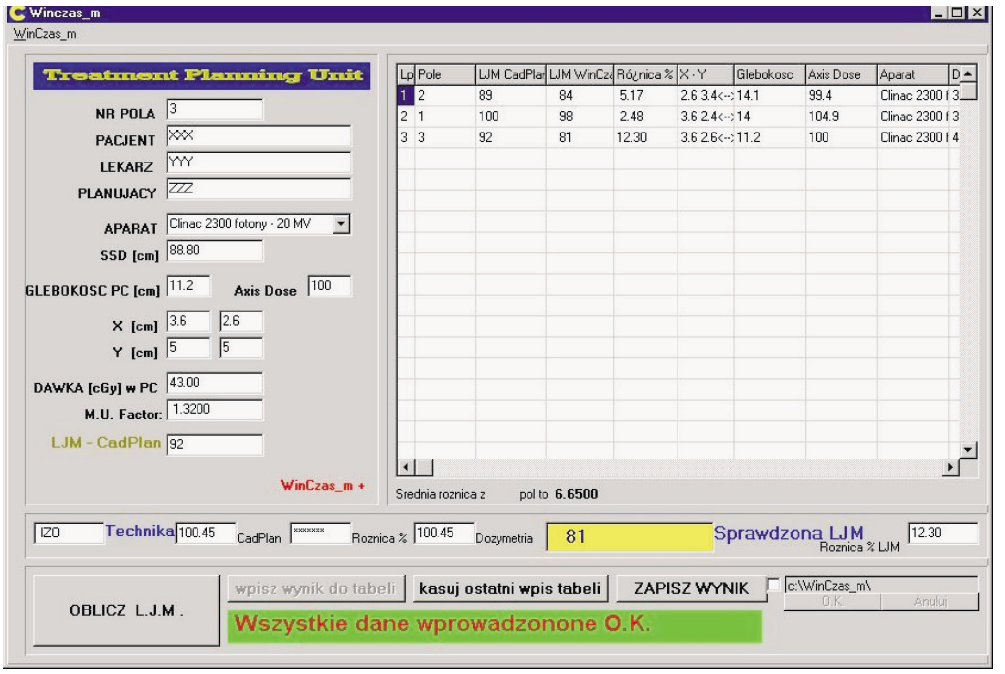

Figure 4. WinCzas®- independent MU calculation program

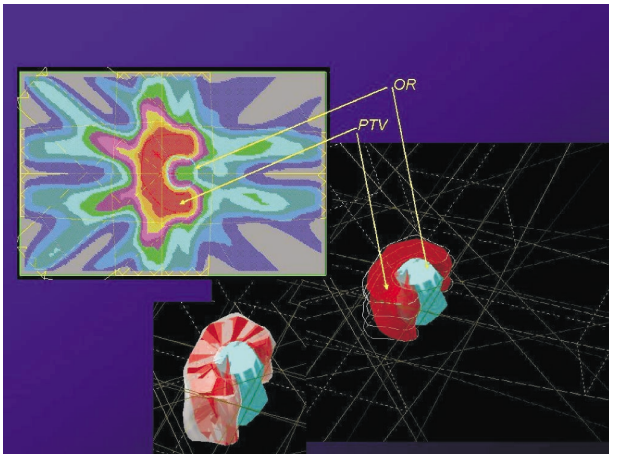

Figure 5. Example of IMRT dose distribution (PTV – Planning Target Volume, OR – Organ at Risk, here: spinal cord)

re" of dose distribution in 3D and the results are a worthy reward for the time spent (Figure 5).

Summary

IMRT opens new possibilities before radiation oncology:
- treatment of previously inaccessible areas (better patient safety)
- better protection of normal tissues
- dose escalation to the selected structures

IMRT requires new ways of thinking during the planning process (inverse planning with optimization), new organization of the routine workday in radiotherapy departments and more precise verification on each level of planning and treatment.

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References

1. Macklis R, Weinhous M, Harnish G. Intensity-modulated radiotherapy: rethinking basic treatment planning paradigms. *Int J Rad Oncol Biol Phys* 2000; 48: 317-318.
2. Teh BS, Woo SY, Butler B. Intensity Modulated Radiation Therapy (IMRT): A new promising technology in radiation oncology. *The Oncologist* 1999; 4: 433-442.
3. www.radimage.com. IMRT Quality Control Solved.
4. www.radimage.com. Quality Assurance and Quality Control for Radiation Therapy.
5. James HV, Atherton S, Budgell GJ et al. Verification of dynamic multileaf collimation using an electronic portal imaging device. *Phys Med Biol* 2000; 45: 495-509.
6. Yan D, Lockman D. Organ/patient geometric variation in external beam radiotherapy and its effects. *Med Phys* 2001; 28: 593-602.
7. Curtin-Savard AJ, Podgorsak EB. Verification of segmented beam delivery using a commercial electronic portal imaging device. *Med Phys* 1999; 26: 739-742.
8. Evans PM, Patridge M, Richard J et al. Sampling consideration for modulated radiotherapy verification using electronic portal imaging. *Med Phys* 2001; 28: 543-552.
9. Pasma KL, Dirkx ML, Kroonwijk M et al. Dosimetric verification on intensity modulated beams produced with dynamic multileaf collimation using an electronic portal imaging device. *Med Phys* 1999; 26: 2373-2378.
10. Meyer J, Mills JA, Haas OC et al. Some limitations in practical delivery of intensity modulated radiation therapy. *Br J Radiol* 2000; 73: 854-863.
11. Nutting C, Dearnaley DP, Webb S. Intensity modulated radiation therapy: a critical review. *Br J Radiol* 2000; 73: 459-469.